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Global warming and renewable energy sources for sustainable development: A case study in Turkey

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Abstract

Renewable energy sources have been important for humans since the beginning of civilization. For centuries and in many ways, biomass has been used for heating and cooking. Many centuries ago mankind was already utilizing the clearly visible power of water for mechanical drive purposes, as was also the case with wind. On the other hand, Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades. It is expected that the demand for electric energy in Turkey will be 300 billion kWh by the year 2010 and 580 billion kWh by the year 2020. Turkey is heavily dependent on expensive imported energy resources that place a big burden on the economy and air pollution is becoming a great environmental concern in the country. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources. This article presents a review of the potential and utilization of the renewable energy sources in Turkey.

Keywords: Energy utilization; Renewable energy; Geothermal; Hydropower; Solar; Biomass

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Contents

1. Introduction

Energy is essential to economic and social development and improved quality of life in all countries. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country. On the other hand, electricity supply infrastructures in many developing countries are being rapidly expanded as policymakers and investors around the world increasingly recognize electricity's pivotal role in improving living standards and sustaining economic growth [1–3].

Climate change is one of the most difficult challenges facing the world today and preventing will necessitate profound changes in the way we produce, distribute and consume energy. Burning fossil fuels such as coal, oil and gas provides about three-quarters of the world's energy. However, when these same fuels are burned, they emit greenhouse gases (GHGs) that are now recognized as being responsible for climate change [4–6]. These fuels are ubiquitous. Fossil energy has fuelled industrial development, and continues to fuel the global economy. We each use energy in many forms every day: heating, cooking, lighting, TV, commuting, working, shopping etc., and almost every activity requires energy. Beyond daily individual use, modern societies use even more

energy for agriculture, industrial processes and freight transport. The primary GHG emitted through fuel combustion is carbon dioxide (CO_2). Land-use and land-use changes, notably deforestation, also involve emissions of carbon dioxide. Other GHGs are also emitted during energy use, the most significant of which are methane (CH_4) and nitrous oxide (N_2O) [7,8].

2. Energy use, global warming and renewables

2.1. Energy use

An energy system is made up of an energy supply sector and energy end-use technologies. The objective of an energy system is to deliver to consumers the benefits that energy use offers. The term energy services is used to describe these benefits, which for households include illumination, cooked food, refrigeration, air conditioning, telecommunications, education, and transportation. Energy services are also required for virtually every commercial and industrial activity. For instance, heating and cooling are needed for many industrial processes, motive power is needed for agriculture and industry, and electricity is needed for telecommunications and electronics. It is the availability of and access to energy services, not merely energy supply, that is crucial [9].

Energy services result from a combination of various technologies, infrastructure (capital), labor (know how), materials, and primary energy. Each of these inputs carries a price tag, and they are partly substitutable for one another. From the consumer's perspective, the important issues are the economic value or utility derived from the services. Consumers are often unaware of the upstream activities required to produce energy services [10].

Per capita use of primary energy in North America was 280 GJ in 2000. In OECD Europe and OECD Pacific—developed countries in those regions—per capita energy use was about 142 and 180 GJ, respectively. On the other hand, Table 1 shows 2001 global

Table 1
Primary energy use by region in 2001

Region	TPES[a] (Gtoe)	Population (billions)	Toe/capita	Growth rate 1990–2001 (%/yr)
1. OECD (all industrialized countries)	5.33	1.14	4.68	1.52
2. Commonwealth of independent States and Eastern Europe	1.03	0.35	2.98	−3.26
3. Sub-Saharan Africa	0.40	0.67	0.60	2.23
4. Middle East and North Africa	0.50	0.31	1.62	4.65
5. Asia Pacific (non-OECD) with China	2.31	3.21	0.72	3.18
6. Latin America and the Caribbean (without Mexico)	0.45	0.42	1.07	2.64
World	10.03	6.10	1.64	1.41
Developing countries (3 + 4 + 5 + 6)	3.66	4.62	0.79	3.19

Source: Ref. [11].

[a]Total primary energy supply (TPES) is the indigenous production of energy, plus imports and positive stock changes, minus exports and international marine bunkers.

primary energy use and fossil fuels (oil, natural gas, and coal) represent nearly 80% of the total. Nuclear power contributes approximately 7%; however, because nuclear power plants have only one-third of thermal efficiency, the final electricity generated for consumption is basically the same as that generated by large hydropower. Large hydropower and "new" renewables (which includes modern uses of biomass and small hydropower, geothermal, wind, solar, and marine energy) each contribute slightly more than 2%; the percentage contribution of "new renewable energy sources" has changed little in recent years [11–14].

2.2. Global warming

Global warming is of course the reason why there is a need to avoid producing carbon dioxide (CO_2). Gases like CO_2 travel up into the upper atmosphere (the troposphere) where they act as a screen to sunlight. They allow the suns rays in but stop the heat radiation from re-emerging, much as happens with the glass in greenhouse. The result is that the greenhouse, in this case the whole world, heats up. Table 2 shows global natural and anthropogenic emissions of SO_2 and NO_x. Some degree of global warming is actually vitial, otherwise this planet would be too cold to support life. However, the vast tonnage of CO_2 gas we have released into the atmosphere seems likely to upset the natural balance. Table 3 also shows world CO_2 emissions by region [1–3].

The results of global warming, if it happens on a significant scale, are likely to be even more severe. It should be remembered that the ice age only involved a global temperature variation of around 4 °C [14]. Global warming could result in the icecaps melting and this, coupled with the effects of the thermal expansion of the seas, would cause sea levels to rise. On the other hand, global warming could also lead to the disruption of crop growing as climate patterns change. It would not be simply a matter of increased temperatures such as the climate system would become erratic, with more storms and more droughts [4–6].

Given that the impact of global warming on life on earth could be very dramatic, insurance companies around the world are already taking the issue seriously. Some even claim that the effects have already started. Most scientists are not yet prepared to pronounce finally on this, although the consensus is that global warming is a strong likelihood. For example, the Intergovernmental Panel on Climate Change (IPCC)

Table 2
Global natural and anthropogenic emissions of SO_2 and NO_x

	SO_2 emissions (Tg/yr)	NO_x emissions (Tg/yr)
Industrial and utility activities	76	22
Biomass burning	2.2	6
Volcanoes	9.3	
Lightning		5
Biogenic emissions from land areas	1.0	15
Biogenic emissions from oceans	24	
Total anthropogenic emissions	78.2	27
Total natural emissions	34.3	21
Total emissions	112.5	48

Source: Ref. [5].

Table 3
World carbon dioxide emissions by region, 1990–2025

Region	1990	2002	2010	2015	2020	2025
Mature market economies	10,465	11,877	13,080	13,745	14,392	15,183
North America	5769	6701	7674	8204	8759	9379
Western Europe	3413	3549	3674	3761	3812	3952
Mature Market Asia	1284	1627	1731	1780	1822	1852
Transitional economies	4894	3124	3643	3937	4151	4386
Emerging economies	6101	9408	13,478	15,602	17,480	19,222
Asia	3890	6205	9306	10,863	12,263	13,540
Middle East	845	1361	1761	1975	2163	2352
Africa	655	854	1122	1283	1415	1524
Central and South America	711	988	1289	1480	1639	1806
Total world	21,460	24,409	30,201	33,284	36,023	38,790

Source: Ref. [18].

suggested that, on the basis of the most up-to-date models, average global temperatures were likely to rise by between 1.0 and 3.5 °C by the year 2100, with 2 °C being their best estimate. This might lead to average sea level rises of between 15 and 95 cm by 2100, the best estimate being 50 cm [14].

2.3. Global renewable energy sources

Renewable energy supplies 17% of the world's primary energy, counting traditional biomass, large hydropower and "new" renewables such as small hydro, modern biomass, wind, solar, geothermal, and biofuels. Traditional biomass, primarily for cooking and heating, represents about 9% and is growing slowly or even declining in some regions as biomass is used more efficiently or replaced by more modern energy forms. Large hydropower is slightly less than 6% and growing slowly, primarily in developing countries. New renewables are 2% and growing very rapidly in developed countries and in some developing countries [15–20].

Renewable energy competes with conventional fuels in four distinct markets: power generation, hot water and space heating, transport fuels, and rural (off-grid) energy as given in Table 4. In power generation, renewable energy comprises about 4% of power-generating capacity and supplies about 3% of global electricity production (excluding large hydropower). Hot water and space heating for tens of millions of buildings is supplied by solar, biomass, and geothermal. Solar thermal collectors alone are now used by an estimated 40 million households worldwide. Biomass and geothermal also supply heat for industry, homes, and agriculture. In developing countries, 16 million households cook and light their homes from biogas, displacing kerosene and other cooking fuel; more than 2 million households light their homes with solar PV; and a growing number of small industries, including agro-processing, obtain process heat and motive power from small-scale biogas digesters [18–20].

The fastest growing energy technology in the world has been grid-connected solar PV, with total existing capacity increasing from 0.16 GW at the start of 2000 to 1.8 GW by the end of 2004, for a 60% average annual growth rate during the 5-year period. During the same period, other renewable energy technologies grew rapidly as well: wind power 28%,

Table 4
Renewable energy indicators

Indicator	Existing capacity end of 2004
Power generation (GW)	
Large hydropower	720
Small hydropower	61
Wind turbines	48
Biomass power	39
Geothermal power	8.9
Solar PV, off-grid	2.2
Solar PV, grid-connected	1.8
Solar thermal power	0.4
Ocean (tidal) power	0.3
Total renewable power capacity (excluding large hydropower)	160
Hot water/space heating (GWth)	
Biomass heating	220
Solar collectors for hot water/Heating (glazed)	77
Geothermal direct heating	13
Geothermal heat pump	15
Households with solar hot water	40 million
Buildings with geothermal heat pumps	2 million
Transport fuels (l/yr)	
Ethanol production	31 billion
Biodiesel production	2.2 billion
Rural (off-grid) energy	
Household-scale biogas digesters	16 million
Small-scale biomass gasifiers	NA
Household-scale solar PV systems	2 million
Solar cookers	1 million

Source: Ref. [20].

biodiesel 25%, solar hot water/heating 17%, off-grid solar PV 17%, geothermal heat capacity 13%, and ethanol 11%. Other renewable energy power generation technologies, including biomass, geothermal, and small hydro, are more mature and growing by more traditional rates of 2–4% per year. Biomass heat supply is likely growing by similar amounts, although data are not available. These growth rates compare with annual growth rates of fossil fuel-based electric power capacity of typically 3–4%, a 2% annual growth rate for large hydropower, and a 1.6% annual growth rate for nuclear capacity during the 3-yr period 2000–2002 [12,13,20].

Existing renewable electricity capacity worldwide totaled 160 GW in 2004, excluding large hydro. Small hydro and wind power account for two-thirds of this capacity. This 160 GW compares to 3800 GW installed capacity worldwide for all power generation. Developing countries as a group, including China, have 70 GW of the 160 GW total, primarily biomass and small hydro power. The European Union has 57 GW, a majority of which is wind power. The top five individual countries are China (37 GW), Germany (20 GW), the USA (20 GW), Spain (10 GW), and Japan (6 GW) [21–27].

Large hydro supplied 16% of global electricity production in 2004, down from 19% a decade ago. Large hydro totaled about 720 GW worldwide in 2004 and has grown

historically at slightly more than 2% per year. Norway is one of several countries that obtain virtually all of their electricity from hydro. The top five hydropower producers in 2004 were Canada (12% of world production), China (11.7%), Brazil (11.4%), the USA (9.4%), and Russia (6.3%). Other developing countries also invest significantly in large hydro, with a number of plants under construction [18–21].

Small hydropower has developed worldwide for more than a century. More than half of the world's small hydropower capacity exists in China, where an ongoing boom in small hydro construction added nearly 4 GW of capacity in 2004. Other countries with active efforts include Australia, Canada, India, Nepal, and New Zealand. Small hydro is often used in autonomous (not grid-connected) village-power applications to replace diesel generators or other small-scale power plants or to provide electricity for the first time to rural populations [15–17]. In the last few years, more emphasis has been put on the environmental integration of small hydro plants into river systems in order to minimize environmental impacts, incorporating new technology and operating methods [21].

Wind power markets are concentrated in a few primary countries, with Spain, Germany, India, the United States, and Italy leading expansion in 2004. Several countries are now taking their first steps to develop large-scale commercial markets. In the case of China, most wind power investments historically have been donor- or government-supported, but a shift to private investment has been underway in recent years. On the other hand, offshore wind power markets are just emerging. About 600 MW of offshore wind exists, all in Europe. The first large-scale offshore wind farm (170 MW) was completed in 2003 in Denmark, and ambitious plans exist for over 40 GW of development in Europe, particularly in Germany, the Netherlands, and the UK [22,23].

Biomass electricity and heat production is slowly expanding in Europe, driven mainly by developments in Austria, Finland, Germany, and the UK. Continuing investments are occurring in Denmark, Finland, Sweden, the US, and several other OECD countries. In Sweden, biomass supplies more than 50% of district heating needs. Among developing countries, small-scale power and heat production from agricultural waste is common, for example from rice or coconut husks. The use of sugar cane waste (bagasse) for power and heat production is significant in countries with a large sugar industry, including Brazil, Columbia, Cuba, India, the Philippines, and Thailand. Increasing numbers of small-scale biomass gasifiers are finding application in rural areas [15,16,20].

Like small hydro, geothermal energy has been used for electricity generation and heat for a century. There are at least 76 countries with geothermal heating capacity and 24 countries with geothermal electricity. Most of the geothermal power capacity in developed countries exists in Italy, Japan, New Zealand, and the USA [24]. On the other hand, geothermal direct-heat utilization capacity nearly doubled from 2000 to 2005, an increase of 13 GWth, with at least 13 new countries using geothermal heat for the first time. Iceland leads the world in direct heating, supplying some 85% of its total space-heating needs from geothermal. About half of the existing geothermal heat capacity exists as geothermal heat pumps, also called ground source heat pumps. These are increasingly used for heating and cooling buildings, with nearly 2 million heat pumps used in over 30 countries, mostly in Europe and the USA [20,24].

Grid-connected solar PV installations are concentrated in three countries: Japan, Germany, and the United States, driven by supportive policies. By 2004, more than 400,000 homes in these countries had rooftop solar PV feeding power into the grid. This market grew by about 0.7 GW in 2004, from 1.1 GW to 1.8 GW cumulative installed

capacity. Around the world, there are also a growing number of commercial and public demonstrations of building integrated solar PV. Typical examples include a subway station (100 kW), gas station (30 kW), solar PV manufacturing plant (200 kW), fire station (100 kW), city hall (50 kW), exhibition hall (1000 kW), museum (10 kW), university building (10 kW), and prison (70 kW) [12,13,25].

The concentrating solar thermal power market has remained stagnant since the early 1990s, when 350 MW was constructed in California due to favorable tax credits. Recently, commercial plans in Israel, Spain, and the USA have led a resurgence of interest, technology evolution, and potential investment. In 2004, construction started on a 1 MW parabolic trough in Arizona, the first new plant anywhere in the world since the early 1990s. Spain's market is emerging, with investors considering two 50 MW projects in 2005. Some developing countries such as India, Egypt, Mexico, and Morocco, have planned projects with multilateral assistance, although the status of some of these projects remains uncertain [25].

Solar hot water/heating technologies are becoming widespread and contribute significantly to the hot water/heating markets in China, Europe, Israel, Turkey, and Japan. China accounts for 60% of total installed capacity worldwide. The European Union accounts for 11% [26], followed by Turkey with 10% and Japan with 7%. Total sales volume in 2004 in China was 13.5 million m^2, a 26% increase in existing capacity. In Japan, existing solar hot capacity continues to decline, as new installations fall short of retirements. In Europe, about 1.6 million m^2 was installed in 2004, partly offset by retirements of older existing systems. The 110 million m^2 of installed collector area give 80 GWth capacity worldwide translates into almost 40 million households worldwide now using solar hot water. This is 2.5% of the roughly 1600 million households that exist worldwide [12,13,20,26].

Biofuels production of 33 billion liters in 2004 compares with about 1200 billion liters annually of gasoline production worldwide. Brazil has been the world's leader of fuel ethanol for more than 25 yr. It produced about 15 billion liters of fuel ethanol in 2004, contributing slightly less than half the world's total. All fueling stations in Brazil sell both pure ethanol and gasohol, a 25% ethanol/75% gasoline blend. In 2004, almost as much ethanol as gasoline was used for automobile (non-diesel) fuel in Brazil; that is, ethanol blended into gasohol or sold as pure ethanol accounted for 44% of total automobile fuel sold in Brazil [11–13,27].

3. Energy utilization and environmental issues in Turkey

3.1. Energy utilization

Turkey is an energy importing country; more than half of the energy requirement has been supplied by imports. Oil has the biggest share in total primary energy consumption. Due to the diversification efforts of energy sources, use of natural gas that was newly introduced into Turkish economy, has been growing rapidly. Turkey has large reserves of coal, particularly of lignite. The proven lignite reserves are 8.0 billion tons. The estimated total possible reserves are 30 billion tons. On the other hand, Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades. It is expected that the demand for electric energy in Turkey will be

300 billion kWh by the year 2010 and 580 billion kWh by the year 2020. Turkey's electric energy demand is growing about 6–8% yearly due to fast economic growing [28–35].

In 2005, primary energy production and consumption has reached 34 and 130 million tons of oil equivalent (mtoe), respectively (Tables 5 and 6). The most significant developments in production are observed in hydropower, geothermal, solar energy and coal production. Turkey's use of hydropower, geothermal and solar thermal energy has increased since 1990. However, the total share of renewables in total primary energy supply (TPES) has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system. Turkey has recently announced that it will reopen its nuclear program in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports. On the other hand, as of the end of 2005, installed capacity and generation capacity of power plants reached 41,457 MW and 176,234 GWh, respectively (Table 7).

The TPES in Turkey grew by 3.0% per year between 1990 and 2005, the fastest growth rate among IEA Member countries. Oil is the dominant fuel, accounting for 40% of TPES in 2005. Coal (28%) and gas (19%) also contributed significantly (Table 6). Renewable energy, mostly biomass, waste and hydropower, accounted for 13%. Hydropower

Table 5
Present and future total final energy production in Turkey (mtoe)

Energy sources	1990	2000	2005	2010	2020	2030
Coal and lignite	12.41	13.29	20.69	26.15	32.36	35.13
Oil	3.61	2.73	1.66	1.13	0.49	0.17
Gas	0.18	0.53	0.16	0.17	0.14	0.10
Com. renewables and wastes[a]	7.21	6.56	5.33	4.42	3.93	3.75
Nuclear	—	—	—	—	7.30	14.60
Hydropower	1.99	2.66	4.16	5.34	10.00	10.00
Geothermal	0.43	0.68	0.70	0.98	1.71	3.64
Solar/wind/other	0.03	0.27	0.22	1.05	2.27	4.28
Total production	25.86	26.71	34.12	39.22	58.20	71.68

Source: Refs. [28,31].
[a]Comprises solid biomass, biogas, industrial waste and municipal waste.

Table 6
Present and future total final energy consumption in Turkey (mtoe)

Energy sources	1990	2000	2005	2010	2020	2030
Coal and lignite	16.94	23.32	35.46	39.70	107.57	198.34
Oil	23.61	31.08	40.01	51.17	71.89	102.38
Gas	2.86	12.63	42.21	49.58	74.51	126.25
Com. renewables and wastes[a]	7.21	6.56	5.33	4.42	3.93	3.75
Nuclear	—	—	—	—	7.30	14.60
Hydropower	1.99	2.66	4.16	5.34	10.00	10.00
Geothermal	0.43	0.68	1.89	0.97	1.71	3.64
Solar/wind/other	0.03	0.27	0.22	1.05	2.27	4.28
Total primary energy consumption	53.01	77.49	129.63	152.22	279.18	463.24

Source: Refs. [28,31].
[a]Comprises solid biomass, biogas, industrial waste and municipal waste.

Table 7
Electric power capacity development in Turkey

Fuel type	2005		2010		2020	
	Installed capacity (MW_e)	Generation (GWh)	Installed capacity (MW_e)	Generation (GWh)	Installed capacity (MW_e)	Generation (GWh)
Coal	14,465	48,386	16,106	104,040	26,906	174,235
Natural gas	10,756	66,417	18,923	125,549	34,256	225,648
Fuel oil	2124	10,531	3246	18,213	8025	49,842
Renewables[a]	14,112	50,900	25,102	86,120	30,040	104,110
Nuclear	0.0	0.0	2000	14,000	10,000	70,000
Total	41,457	176,234	65,377	347,922	109,227	623,835

Source: Refs. [31,32].
[a]Renewables includes hydropower, biomass, solar and geothermal energy.

represented 5% of TPES in 2005. Biomass, primarily fuel wood consumed by households, represented almost 9%. The economic downturn in Turkey in 2000/2005 caused TPES to decline by 6.0%. But energy demand is expected to more than double by 2010, according to Turkish government sources [28,31].

The share of renewables in TPES decreased from 18% in 1990 to 14.5% in 2005. The fall in share was the result of a considerable decline in biomass supply and a levelling off of hydropower. Renewables represent the second-largest domestic energy source after coal. But the share of renewables, particularly biomass, is expected to continue to decrease as oil and gas penetrate the residential sector and biomass becomes scarcer.

Gas accounted for 38% of total electricity generation in 2005, coal 28% and oil at about 7%. Hydropower is the main indigenous source for electricity production and represented 27% of total generation in 2005 (see Table 7). Hydropower declined significantly relative to 2000 due to lower electricity demand and to take-or-pay contracts in the natural gas market. According to Turkish statistics, the share of hydropower in electricity generation increased to 26% in 2002 [28–33].

3.2. Greenhouse gas emissions

Turkey has been undergoing major economic changes in the 1990s, market by rapid overall economic growth and structural changes. However, the share of the informal sector in the Turkish economy remains high. Turkey's population has reached 72 million and remains one of the fastest growing from 1990 to 2004 in the OECD. Major migrations from rural areas to urban, industrial and tourist areas continue. In this context, Turkey confronts the challenge of ensuring that economic growth is associated with environmental and social progress, namely that its development is sustainable [29].

Turkey ratified the Framework Convention on Climate Change in February 2004 and is developing its climate change strategy. After that, on May 24, 2004 Turkey became the 189th party by signing Framework Convention on Climate Changes. In the first 6 months after Turkey became a party of FCCC, the country is obligated to first national declaration to United Nations General Secretariat until November 24, 2004. After this stage is completed Turkey will both have to fulfill new liabilities such as to present national GHG

inventories and national declaration reports to Convention Secretariat regularly, and will also actively participate in efforts carried on global wide so that convention will achieve its ultimate goal. In 2003, it is estimated that 36% of CO_2 emissions occurred due to energy, 34% due to industry, 15% due to transportation and 14% due to other sectors such as housing, agriculture and forestry and in 2020 40% will occur due to energy, 35% due to industry, 14% due to transportation and 11% due to other sectors. [28,33].

4. Renewable energy potential and utilization in Turkey

4.1. Renewable energy supply

Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. Total renewable energy supply declined from 1990 to 2004, due to a decrease in biomass supply. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources [13,28].

4.2. Research and development trends

Turkey spent a total of US$ 120 million (2005 prices and exchange rates) on government energy RD&D between 1980 and 2005. In this period, 15.6% of its total energy research and development (R&D) budget (US$17.4 million) was allocated to renewable energy. Government R&D expenditures for renewables followed the general trend in overall energy R&D expenditures, rising in the late 1980s and then falling in the early 1990s. Public funding increased substantially in 1997.

Among the renewable technologies, geothermal received the most sustained funding over the past two decades and the highest level of funding, equivalent to US$6.1 million or 37% of the renewables R&D expenditures between 1980 and 2005. In addition, Turkey participates in international collaborative R&D in Photovoltaic Power Systems through the IEA Implementing Agreements [31–35].

4.3. Market deployment trends

Market deployment policies for renewables started in 1984 with third-party financing, excise and sales tax exemptions. Capital grants were offered in 2001. The Turkish government's approach to the deployment of renewables reflects its priorities to develop indigenous and renewable resources in conjunction with the expansion of privately owned and operated power generation from renewable sources [13].

The build-own-transfer (BOT) and the build-own-operate (BOO) schemes were put in place in 1984 and financed major power projects (not limited to renewables) with the main objective of attracting private investors. BOT projects were granted a treasury guarantee. Although BOT and BOO approaches attracted significant investment, they also created large contingent public obligations with the government covering the market risk through take-or-pay contracts. The economic crisis of 2000 and pressure from the International Monetary Fund, however, brought an end to the treasury guarantees, except for the 29

BOT projects whose contracts were already in place. The BOT and BOO financing schemes ended in 2000 and were replaced in 2001 by financial incentives within the framework of the Electricity Market Law. The Electricity Market Licensing Regulation of the Electricity Market Law (Law Number 4628) contains two regulations pertaining to the promotion of the use of renewable energy [13]:

- Entities applying for construction licenses for renewable energy facilities only pay 1% of the total license fee. In addition, renewable energy generation facilities do not pay annual license fees for the first 8 yr after the facility completion date specified in the licenses.
- The Turkish Electricity Transmission Company (TEIAS) and/or distribution companies are required to assign priority status for grid connection of renewable generating facilities.

The real beginning for renewable energy policy was the definition of renewable energy sources in the decree of the Modification of the License Regulation in the Electricity Market in 2003. Before then, there was no national renewable energy policy and few government incentives existed to promote market deployment of renewable energy. However, the Electricity Market Licensing Regulation, in itself, is not expected to be sufficient to overcome the high investment cost, risk and lack of security associated with the entrance of renewable power plants into the electricity market [13,28].

Turkey is to be the recipient of a US$202 million renewable energy loan provided by the World Bank to be disbursed as loans via financial intermediaries to interested investors in building renewable energy sourced electricity generation. These loans are expected to finance 30–40% of associated capital costs. The aim of the Renewable Energy Program is to increase privately owned and operated power generation from renewables sources within a market-based framework, which is being implemented in accordance with the Electricity Market Law and the Electricity Sector Reform Strategy. This program will assist the Directorate of the Ministry of Energy and Natural Resources (MENR) in the preparation of a renewable energy law, as well as to define the required changes and modifications related to legislation such as the Electricity Market Law to better accommodate greater private sector involvement [31–33].

The MENR, together with the Electrical Power Resources Survey and Development Administration (EIEI), currently are engaged in the preparation of renewable energy and energy efficiency laws. The renewable energy law is expected to be adopted by the second quarter of 2004. It is anticipated that the law will institute measures such as feed-in tariffs and investment incentives. On the other hand, there is significant renewable energy opportunity in Turkey, but few measures have been employed to tap into that potential. Since the 1980s, Turkey's energy policy has concentrated on efforts to stimulate private investment to meet the increasing internal energy demand [31].

4.4. Hydropower

There are 436 sites available for hydroelectric plant construction, distributed on 26 main river zones. Table 8 gives water and hydroelectric energy potential of selected river basins in Turkey. The total gross potential and total energy production capacity of these sites are nearly 50 GW and 112 TWh/yr, respectively, and about 30% of the total gross potential

Table 8
Economic hydroelectric potential of selected river basins in Turkey

Name of river basins	Number of HEPP projects	Installed capacity (MW)	Average Gener. (GWh)	Energy firm (GWh)
B. Akdeniz	23	673.7	2534	953
Antalya	20	1432.8	5163	2092
Sakarya	22	1095.7	2373	1436
B. Karadeniz	21	624	2176	1205
Yeşilırmak	24	1259	5297	4266
Kızılırmak	28	2093.5	6320	4114
D. Akdeniz	30	1389.5	5029	2904
Seyhan	27	2000.8	7571	3711
Ceyhan	13	1413.2	4652	2797
Fırat	79	9648.2	37,961	30115
D. Karadeniz	58	3307.5	11,062	5232
Çoruh	30	3133.9	10,540	6419
Aras	13	587.9	2287	1807
Dicle	47	5050.9	16,751	10,385
Total Turkey	485	34,728.4	123,039.9	79,145.9

Source: Ref. [36].

Table 9
Distribution of the hydropower potential in Turkey by Project implementation status

	Number of project	Installed capacity (MW)	Total annual power generation capacity			
			Firm (GWh)	Mean (GWh)	Cumulative (GWh)	Mean (%)
In operation	130	12,251	32,984	44,388	44,034	35.0
Under construction	31	3338	6467	10,845	55,233	9.0
Final design completed	19	3570	7029	10,897	66,130	9.0
Under final design operation	21	1333	2492	4494	70,624	4.0
Planned	119	6091	10,861	22,324	92,948	18.0
Under planning	57	1978	4214	7602	100,550	6.0
Master plan completed	40	2691	5674	9195	109,745	7.0
Reconnaissance completed	107	3920	8523	15,184	124,929	12.0
Initial study completed	42	368	526	1180	126,109	1.0
Total potential	566	35,540	78,770	125,129		100.0

Source: Ref. [36].

may be economically exploitable. At present, only about 35% of the total hydroelectric power potential is in operation (see Table 9). The national development plan aims to harvest all of the hydroelectric potential by 2010. The contribution of small hydroelectric plants to total electricity generation is estimated to be % 5–10 [36–38].

The Southeastern Anatolia Project (GAP) is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3 million ha of agricultural land. This is over 10% of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated are in Turkey. The GAP project on the Euphrates and Tıgris Rivers encompasses 22 dams and 19 hydroelectric power plants. Once completed, 27 billion kWh of electricity will be generated and irrigating 1.7 million ha [37].

4.5. Fuelwood and biomass

Among the renewable energy sources, biomass is important because its share of total energy consumption is still high in Turkey. Since 1980, the contribution of the biomass resources in the total energy consumption dropped from 20% to 8% in 2005. Biomass in the forms of fuelwood and animal wastes is the main fuel for heating and cooking in many urban and rural areas [39–45]. The total recoverable bioenergy potential is estimated to be about 16.92 mtoe in 1998 [45]. The estimate is based on the recoverable energy potential from the main agricultural residues, livestock farming wastes, forestry and wood processing residues, and municipal wastes that given in Ref. [42]. Table 10 shows the present and planned biomass energy production in Turkey. As seen in Table 10, total biomass production is 7.3 mtoe in 2005 and will be 52.5 mtoe in 2030.

Using vegetable oils as fuel alternatives has economic, environmental, and energy benefits for Turkey. Vegetable oils have heat contents approximately 90% of that of diesel fuel. A major obstacle deterring their use in the direct-injection engine is their inherent high viscosities, which are nearly ten times that of diesel fuel. The overall evaluation of the results indicated that these oils and biodiesel can be proposed as possible candidates for fuel. On the other hand, organic wastes are of vital importance for the soil, but in Turkey most of these organic wastes are used as fuel through direct combustion. Animal wastes are mixed with straw to increase the calorific value, and are then dried for use. This is the principal fuel of many villages in rural region of Turkey, especially in mountainous regions [41–43].

Fuelwood is important for rural area in Turkey as in other developing countries. About half of the world's population depends on fuelwood or other biomass for cooking and other domestic use. In 1998, an estimated 12.5 million steres of fuelwood were produced by

Table 10
Present and planned biomass energy production in Turkey (Ktoe)

Years	Classic biomass	Modern biomass	Total
2005	6494	766	7260
2010	5754	1660	7414
2015	4790	2530	7320
2020	4000	3520	7520
2025	3345	4465	7810
2030	3310	4895	8205
Total	34,658	17,853	52,511

Source: Refs. [31,32].

the state, while from both public and private sectors recorded production was estimated at about 14.2 million steres from undeclared production [45]. In other words, approximately half of the total demand for fuelwood is met by informal cutting in State forests and other sources of fuelwood in agricultural areas.

Turkey is a developing country with rich agricultural potential, but the amount of utilization is very low. In agricultural residues, the total residues amount calculated in dry base has been measured approximately between 40 and 53 million tons [42,45]. If it is accepted that 80% of cereal can be used and its average humidity rate is 15%, then the total amount of agricultural residues used in power plant would be as the average between 27 and 36 million tons. As the average energy equivalent of agricultural residues is 17.5 MJ/kg [42], then the annual energy equivalent of agricultural residues is varies from 470 to 620 PJ. So, agricultural residues have a high potential to take the place of the lignite (40 million tons) and hard coal (1.3 million tons) used in electricity production.

Biogas systems are considered to be strong alternatives to the traditional space heating systems (stoves) in rural Turkey. The economic of biogas systems are compared with traditional heating systems fuelled by wood, coal and wood mixture, and dried animal waste in three different climatic regions in the country. The technical data used in the analysis are based on the experimental results. Seven different comparisons are made between the biogas and traditional systems. The payback periods, cumulated life-cycle savings and the cost of biogas are calculated for a wide range using two unstable economic parameters, discount and inflation rates. The quality of the model and the assumptions are discussed. The results provide evidence of the economic viability of biogas systems over the traditional space heating systems of rural Turkey in many instances [39,43].

4.6. Geothermal energy

Turkey is one of the countries with significant potential in geothermal energy. Data accumulated since 1962 show that there may exist about 4500 MW of geothermal energy usable for electrical power generation in high enthalpy zones. Heating capacity in the country runs at 350 MW_t equivalent to 50,000 households. These numbers can be heightened some sevenfold to 2250 MW_t equal to 350,000 households through a proven and exhaustible potential. Turkey must target 1.3 million house holds equivalent 7700 MW_t. Geothermal central heating, which is less costly than natural gas could be feasible for many regions in the country. In addition 31,000 MW of geothermal energy potential is estimated for direct use in thermal applications. The total geothermal energy potential of Turkey is about 2268 MW in 1998, but the share of geothermal energy production, both for electrical and thermal uses is only 1229 MW (Table 11). There are 26 geothermal district heating systems exist now and main city geothermal district heating systems are in Gönen, Simav and Kırşehir cities [46–49].

4.7. Solar energy

Turkey lies in a sunny belt between 36° and 42°N latitudes. The yearly average solar radiation is 3.6 kWh/m^2-day and the total yearly radiation period is approximately 2640 h, which is sufficient to provide adequate energy for solar thermal applications. Table 12 shows solar energy potential in Turkey. In spite of this high potential, solar energy is not now widely used, except for flat-plate solar collectors. They are only used for domestic hot

Table 11
Capacities in geothermal utilization in Turkey (May 2006)

Geothermal utilization	Capacity
District heating	827 MW_t
Balneological utilization	402 MW_t
Total direct use	1229 MW_t
Power production	20.4 MW_e
Carbon dioxide production	120,000 t/yr

Source: Ref. [47].

Table 12
Solar energy potential for seven regions and some cities in Turkey

Region	Radiation energy	Sunshine duration period				
	Average (kWh/m^2 yr)	Maximum (kWh/m^2 yr)	Minimum (KWh/m^2 yr)	Average (h/yr)	Maximum (h/month)	Minimum (h/month)
Southeast Anatolia	1492	2250	600	3016	408	127
Mediterranean	1453	2112	588	2924	360	102
Central Anatolia	1434	2112	504	2712	381	98
Aegean	1407	2028	492	2726	371	96
East Anatolia	1395	2196	588	2694	374	167
Marmara	1144	1992	396	2528	351	88
Black Sea	1086	1704	408	1966	274	84

Source: Refs. [31,32].

water production, mostly in the sunny coastal regions. In 2004, about 8.0 million m^2 solar collectors were produced and it is predicted that total solar energy production is about 0.290 mtoe [31,32]. The global solar radiation incident on horizontal surface and bring sunshine hours are measured by all recording stations in Turkey. Solar radiation calculations have been performed by several researchers for Turkey that given in Refs. [50–59].

Although solar energy is the most important renewable energy source it has not yet become widely commercial even in nations with high solar potential such as Turkey. Thermosyphon-type flat plate collectors have been used in Turkey since 1950, and at present about 30% of installed systems are still of this type. Typical solar water heaters in Turkey are of the thermosyphon type and consists of two flat-plate solar collectors having an absorber area between 3 and 4 m^2, a storage tank with capacity between 150 and 200 l and a cold water storage tank, all installed on a suitable frame. The cold-water tank is used to store water because, due to shortage problems, the supply is intermittent. However, the installations are mostly by trial and error. There are quite a large number of different manufacturers producing collectors with varying types and performances [60–62].

4.7.1. Solar heating/cooling of buildings

The energy consumption for heating and cooling of buildings in Turkey was about 21.6 mtoe for the year 2005. This is more than one third of the total energy consumption.

The average household in Turkey needs more that 60% of its total energy consumption for space heating. The cooling demand in buildings increased rapidly in south region of the country at the summer season. The reason, beside general climatic and architectural boundary conditions, is an increase in the internal cooling load and higher comfort requirements. These aspects show the huge potential in this field for the implementation of advanced thermal energy storage technologies in Turkey [29–32].

The heating and cooling of buildings can be identified as one of the most promising fields of application for thermal energy storage. Depending on the location and the use of the building, heating or cooling is the main application for the storage system. Due to high insulation standards and high internal heat production in many of today's modern buildings, cooling is necessary even in cold climates. Therefore many buildings in fact need heating and cooling. Some demonstration projects with concerning the use of adsorption systems for cold and hot regions with energy storage in the country should be planned by governments and private sectors. On the other hand, phase change energy storage and chemical reactions can be used for heating and cooling in active or passive systems [63–65]. Active systems are defined by an actively supported charging or discharging process, for example, by ventilated air or a pumped heat transfer fluid. They are coupled to the building's heating or air conditioning system.

4.7.2. Solar drying

Sun drying of agricultural products has been practised all over the world since the dawn of civilization. The methods generally used for basic drying processes were simple, more labor intensive and less quality-control oriented. The characteristic technical problems faced by the basic sun-drying processes were: (a) cloudiness and rain, (b) insect infestation, (c) high level of dust and atmospheric pollution, (d) intrusion from animals and man. However, with the general development of knowledge and technology the human endeavors have been directed for supplanting the traditional drying of crops with certain artificial means in order to achieve better quality control to reduce spoilage and to lessen the losses and inefficiencies of the traditional sun drying methods [66,67].

Drying has a long tradition as a conservation method in Turkey. During the drying season, insect and mold development in harvested crops is promoted due to high air temperature and relative humidity. Furthermore, the intensive solar radiation causes several quality reductions like vitamin losses or color changes in dried crops. In Turkey, solar energy has been used since the dawn of history for the open-air drying of agricultural products such as hazelnut, beans and a variety of other products. There is enough potential for solar drying in Turkey and this potential should be increase by government and private companies [68–70].

4.7.3. Photovoltaic energy

Turkey, currently, does not have an organized photovoltaic (PV) program. Global energy strategies and policies are laid down in periodic 5 yr development plans. Government has no intention in PV production. PV cells are produced in various research establishments in order to study the feasibility of local manufacturing. So far none of these studies yielded a positive result in order to justify a mass production facility in Turkey. There are more than 30,000 small residential areas where solar powered electricity would likely be more economical than grid supply. Another potential for PV market is holiday villages at the long coastal areas.

Table 13
Wind characteristics for some selected cities in Turkey

Station name	Latitude N (°)	Longitude E (°)	Altitude (m)	Average energy density (W/m^2)	Average wind speed (m/s)	
					at 5 m	at 50 m
Anamur	36.06	32.50	5	52	3.1	4.3
Antakya	36.12	36.10	100	84	4.0	5.8
Ayvalık	39.19	26.42	4	54	3.1	4.2
Balıkesir	39.38	27.53	147	58	2.8	4.2
Bandırma	40.21	27.58	58	301	5.8	6.9
Bergama	39.01	27.11	45	61	3.5	4.9
Bodrum	37.02	27.26	27	85	3.7	5.1
Bozcaada	39.50	26.04	40	317	6.2	8.4
Çanakkale	40.08	26.24	2	92	3.9	5.4
Çorlu	41.10	27.47	183	103	3.8	5.3
Gökçeada	40.12	25.54	72	70	3.5	5.5
İnebolu	41.59	33.46	64	63	3.7	5.2
Malatya	38.21	38.19	898	51	2.7	3.7
Mardin	37.18	40.44	1080	114	4.3	6.0
Silifke	36.23	33.56	15	50	2.9	3.9
Sinop	42.02	35.10	32	84	3.6	5.1

Source: Refs. [31,32].

These facilities are frequently far from the main grid nodes and require additional power when solar insolation is high. Unfortunately energy demand in Turkey is so large that utilities are concentrating on large conventional power plants and peak load facilities. The newest 5 yr development plan, being prepared, foresees a more ambitious program and estimates approximately 40 MWp installed power by the year 2010 [30–34,71,72].

4.8. Wind energy

There are a number of cities in Turkey with relatively high wind speeds (see Table 13). These have been classified into six wind regions, with a low of about 3.5 m/s and a high of 5 m/s at 10 m altitude, corresponding to a theoretical power production between 1000 and 3000 kWh/(m^2 yr). The most attractive sites are the Marmara Sea region, Mediterranean Coast, Agean Sea Coast, and the Anatolia inland. Turkey's first wind farm was commissioned in 1998, and has a capacity of 1.5 MW. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities. The majority of proposed projects are located in the Çeşme, İzmir and Çanakkale regions. Electrical power resources survey and development administration (EIE) carries out wind measurements at various locations to evaluate wind energy potential over the country, and have started to compile a wing energy atlas. Approval of independent wind energy projects requires at least a 6 months history of wind measurements [71–75].

5. Future energy and GHG emission projections

Turkey's demand for energy and electricity is increasing rapidly. Since 1990, energy consumption has increased at an annual average rate of 4.3%. As would be expected, the

rapid expansion of energy production and consumption has brought with it a wide range of environmental issues at the local, regional and global levels [76]. With respect to global environmental issues, Turkey's carbon dioxide (CO_2) emissions have grown along with its energy consumption. Emissions in 2000 reached 211 million metric tons [31–33]. Table 14 shows direct GHG emissions in Turkey by sectors between 1990 and 2010 [77].

Based on the demand forecast from MAED, total final energy consumption grows at an average rate of 5.9% per year from 65.5 mtoe (2000) to 273.5 mtoe (2025). Average annual growth rates vary by sector, with industry having the highest rate at 7.6%, followed by the transportation sector with 5.0% [76]. Over 2000–2025, industrial consumption increases from 23.9 to 148.9 mtoe increasing its share from 36% to 54% (see Fig. 1).

In terms of final energy by fuel, hard coal/coke increase their share slightly from 13% to 18%, lignite holds steady at 6%, electricity grows from 17% to 24%, oil products decline from 42% to 29% and natural gas increases from 7% to 17% between 2000 and 2025. The model also projects fuel mixes for each of the consumer groups or demand sectors [76].

Total natural gas consumption is projected to increase at an annual rate of 9.6% from 15.0 to 169.4 billion m^3 (bcm) over 2000–2025. Power sector gas demand is one of the main drivers for this projected growth and will account for 112.8 bcm or 67% of total gas consumption in 2025 (up from 9.3 bcm in 2000). Industrial demand is the fastest growing market segment (11.5% annually) with gas expanding from 2.5 to 38.4 bcm during 2000–2025 and eventually accounting for 23% of total gas consumption (Fig. 2).

Table 14
Direct greenhouse gas emissions in Turkey by sectors between 1990 and 2010 (%)

Greenhouse gases (GHG)	Years					
	1990	1995	1997	2000	2005	2010
Total direct GHG (Gg)[a]	200,720	241,717	271,176	333,320	427,739	567,000
CO_2 (%)	88.67	87.42	88.93	90.93	92.90	94.53
CH_4 (%)	10.77	10.05	9.42	7.68	5.97	4.52
N_2O (%)	0.56	2.53	1.65	1.40	1.14	0.95
Emission fractions generated from fuel consumption						
Direct GHG (Gg)[a]	146,735	172,933	195,591	258,314	352,733	491,995
CO_2 (%)	97.3	97.8	98.0	98.2	98.6	98.9
CH_4 (%)	2.1	1.6	1.5	1.4	1.0	0.7
N_2O (%)	0.6	0.5	0.5	0.4	0.4	0.4
Emission fractions generated from industrial processes						
Direct GHG (Gg)[a]	35,424	47,251	52,929	52,929	52,929	52,929
CO_2 (%)	99.5	89.1	93.5	93.5	93.5	93.5
CH_4 (%)	0.1	0.1	0.1	0.1	0.1	0.1
N_2O (%)	0.4	10.8	6.4	6.4	6.4	6.4
Emission fractions generated from the burning of agricultural residues						
Direct GHG (Gg)[a]	591.05	550.25	578.5	578.5	578.5	578.5
CH_4 (%)	76.92	76.90	76.96	76.96	76.96	76.96
N_2O (%)	23.08	23.10	23.04	23.04	23.04	23.04

Source: Ref. [77].
[a]Direct greenhouse gases, CH_4 and N_2O emission values were given as CO_2 equivalents.

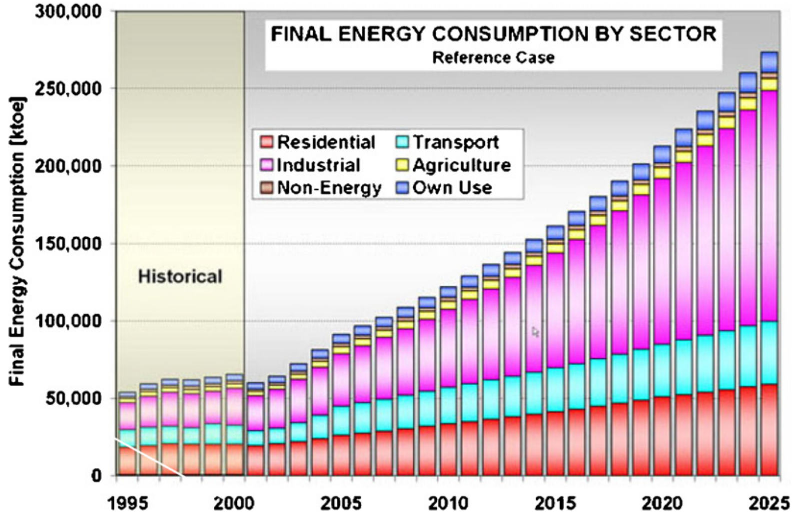

Fig. 1. Reference case final energy consumption by sector in Turkey [76].

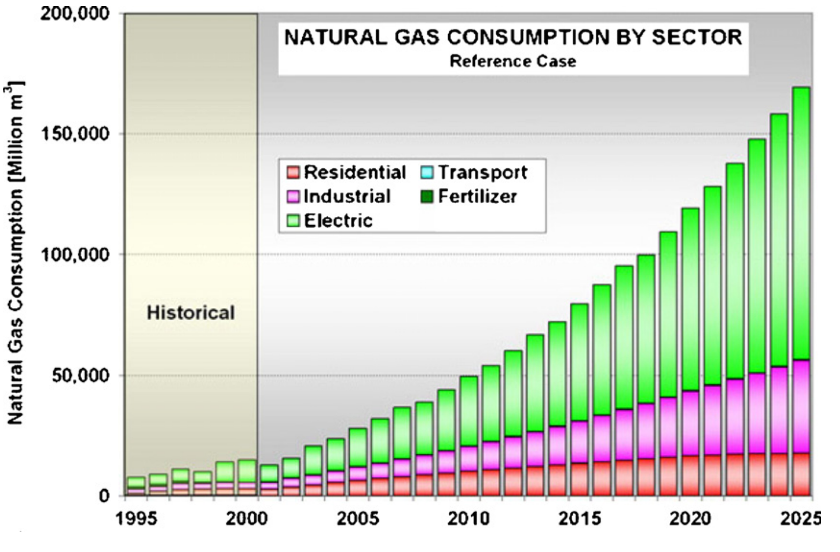

Fig. 2. Reference case gas consumption by sector in Turkey [76].

New capacity additions are projected to total about 108 GW by 2025. WASP results indicate that the majority of the load growth is met with natural gas-fired generation [31–33,76]. By 2025, gas-fired units represent 67% (93 GW) of the installed generating capacity and account for 77% of total generation (588 of 768 TWh).

Primary energy supply is projected to increase from 64.5 mtoe (1995) to 332.0 mtoe (2025). Crude oil imports remain constant at 33.0 mtoe after 2004 when the domestic refineries are forecast to run into their processing capacity, resulting in a drop in crude oil

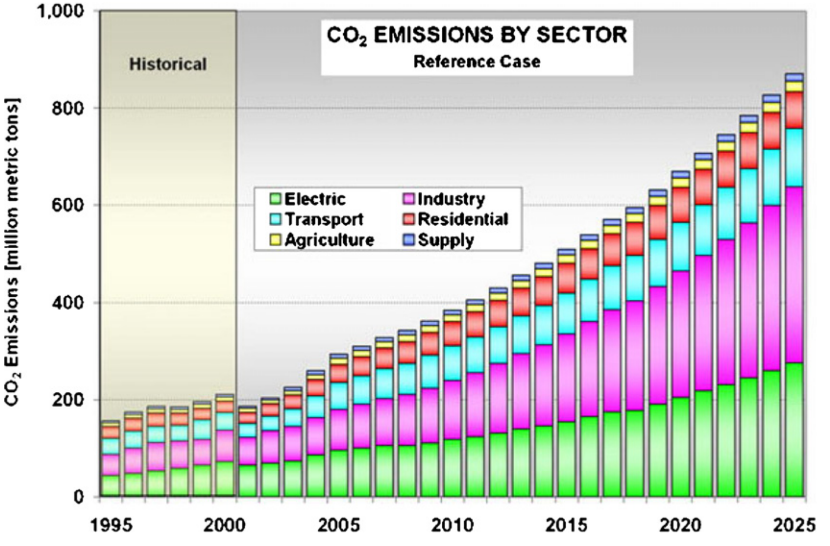

Fig. 3. Reference case CO_2 emissions in Turkey [76].

share from 44% to 10% of total supplies. Once the refining capacity is reached, net imports of refined products quickly grow from 2.6 to 52.3 mtoe (2000–2025), accounting for about 16% of total supplies by 2025. Natural gas quickly increases its share from 10% (6.3 mtoe) in 1995 to 42% (139.8 mtoe) of total supplies in 2025. Although renewables double over 2000–2025, their share decreases from 14% in 2000 to 7% in 2025.

The model projects total CO_2 emissions to increase at an average rate of 5.8%/yr and reach 871 million t/yr by 2025 (Fig. 3). The industrial contribution changes the most noticeably, rising from 31% to 42% driven by the high growth in industrial final energy as well as the continued reliance on solid and liquid fuels in this sector [76].

Total national SO_2 emissions reach their low point as 1.83 million ton/yr in 2001, but it will be more than double value to 3.85 million ton/yr in 2025. The majority of the emissions growth can be attributed to an increase in industrial solid fuel and fuel oil combustion and an associated rise in SO_2 emissions from 566–2411 kt/yr over 2000–2025. By the end of the study period, industry is expected to be responsible for 63% of Turkey's SO_2 emissions [77]. While in 2004, electricity generation accounted for 60% of national sulfur emissions, this share will be down to 24% by 2025. This is in large part because coal generation stays more or less constant while several new sulfur controls are already commissioned and expected to come on-line in the very near term.

Results show that under the Renewables Scenario, 7250 MW of gas-fired capacity is substituted for 19,250 MW of wind and 1107 MW of small hydro over 2000–2025. By 2025, all renewables combined (including large hydro) amount to more than 54 GW or 35% of installed capacity. The additional generation from renewables quickly increases to 53.8 TWh (7% of total) by 2025 and essentially replaces CCGT generation with only minor changes in the dispatch of the other fossil fuel units. Combined with large hydro and geothermal, renewables generate 173.6 TWh (22.6%) of electricity by 2025 [76].

6. Conclusions

Renewable energy technology is unique, demonstrating quite different characteristics, levels of maturity and needs for market success. Hydropower, burning wood for heat and geothermal energy are the most mature renewable technologies, and mostly compete in today's markets without special policy support. They can be cost-competitive where the resource base is strong and where there is ready access to market the energy produced. Hydropower and geothermal energy achieved their current market share through a development path that included a substantial governmental role, while wood burning has been a traditional energy resource for millennia. Less mature, "new" renewables, including wind power, solar technologies and newer forms of bioenergy, are only now entering markets, and like other emerging energy technologies, have received governmental support for both technological development and for market deployment. On the other hand, the world's energy system is at least a 2.0 trillion dollars market dominated by fossil fuels, where small changes can have a large influence on efforts to reach sustainability. Renewable energy sources are key to achieving this goal. Renewable energies are also essential contributors to the energy supply portfolio as they contribute to world energy supply security, reducing dependency of fossil fuel resources, and provide GHGs mitigating opportunities.

Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades. It is expected that the demand for electric energy in Turkey will be 300 billion kWh by the year 2010 and 580 billion kWh by the year 2020. Turkey is heavily dependent on expensive imported energy resources that place a big burden on the economy and air pollution is becoming a great environmental concern in the country (see Table 14). In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources.

Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewables. On the whole, Turkey has substantial reserves of renewable energy sources, including approximately 1% of the total world hydropower potential. There is also significant potential for wind power development. Turkey's geothermal potential ranks seventh worldwide, but only a small portion is considered to be economically feasible.

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